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MEMORANDUM

DATE: March 24, 2017

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SUBJECT: I-90: Four Lakes to Stateline Operations Study
Evaluation and Screening Memorandum #4 P16159-000

This memorandum documents the screening process used to narrow a full-range of transportation system management and operational (TSMO) strategies to a select group of recommended strategies that best meet the needs, goals and operations objectives of the I-90 corridor between Four Lakes and the Idaho Stateline. The recommended strategies will advance to the next phase of study and evaluation, which will provide more detailed analysis of the strategies, and consider more specific implementation details. This memorandum includes an executive summary, the screening methodology, first and second level screening, recommended strategies and locations, lessons learned from past implementations, and the next steps.

EXECUTIVE SUMMARY

Applying a two-level screening process, the project team narrowed a full-range of TSMO strategies, identified in the toolbox provided in Attachment A, to those that best meet the identified needs, goals and operations objectives for the I-90 corridor study area and offer the best potential to improve safety and operations along the corridor. The first level of screening focused on selecting the strategies that could best achieve the project goals and meet the needs of the corridor. Strategies that best met the first level screening criteria, were considered for a second level of screening criteria that included: operational benefits, feasibility factors, implementation cost, and on-going operations and maintenance costs.

After both rounds of screening, the following strategies emerged as the ones with the best potential to improve safety and meet the needs of the I-90 corridor:

- **Active Traffic Management** – Install overhead gantry variable message signs and weather sensors along the freeway that can be used for thee key strategies: variable speed system, queue warning system, and dynamic lane control.
- **Ramp Metering** – Install ramp meters at on-ramps to manage the flow of entering vehicles, reduce crashes at merge areas, and minimize congestion on the mainline.
- **Ramp Closures –** Evaluate the potential to close ramps. Aside from the traffic analysis component of a ramp closure, the socio-economic and political factors need to be fully examined by WSDOT outside the scope of this project.
- **Wrong Way Driver Notification System** – Install detection along off-ramps that can detect wrong way drivers, sending notifications to the traffic management center (TMC) as well as notifying travelers on variable message signs (VMS) or in car navigation systems when possible.
- **Traffic Incident Management Strategies –** Enhance the existing traffic incident management strategies with the following three activities: develop TIM Teams, expand the Dedicated Roving Patrol Program, and establish instant tow contracts
- **Work Zone Management** – Implement work zone management strategies that improve safety in work zones. These strategies apply safety measures that inform drivers of work zone and worker locations, and they support a range of work zone durations from long-term stationary projects to short duration or even mobile projects.

SCREENING METHOD

Applying a two-level screening process, the project team narrowed a full-range of TSMO strategies, identified in the toolbox provided in Attachment A, to those that best meet the identified needs, goals and operations objectives for the I-90 corridor study area and offer the best potential to improve safety and operations along the corridor. The screening levels and applied criteria for each level are shown in the diagram below.

First Level Screening
Narrow to 11 strategies from original toolbox
- Criteria: I-90 corridor goals

Second Level Screening
Narrow to 6 strategies
- Criteria: operational benefits, feasibility, initial cost, and ongoing O&M costs

Implementation Plan
- Advance recommended strategies to the Implementation Plan

FIRST LEVEL SCREENING

The project team assembled a toolbox of TSMO strategies with potential to meet the I-90 project goals along the corridor. The TSMO strategies toolbox includes 31 strategies, organized into five categories:

- Traffic Operations and Management Strategies
- Maintenance and Construction Management Strategies
- Emergency and Incident Management Strategies
- Transit and Demand Management Strategies
- Infrastructure Improvement Strategies

The full toolbox is included as Attachment A:

Criteria – First Level Screening

The initial screening evaluated how well each strategy achieves the project goals. The project management team developed the three goals[1]:

Goal 1: Improve safety performance for all I-90 corridor users

a) Objective: Meet Washington State Safety Plan Target Zero goals of zero traffic fatalities and serious injuries by 2030.
b) Objective: Reduce weather-related crashes.
c) Objective: Reduce rear-end crashes.
d) Objective: Reduce pedestrian and bicycle crashes at ramp terminals.

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[1] I:90 Four Lakes to Idaho Stateline Operations Study. Goals, Operations Objectives, and Needs Memorandum. Prepared for WSDOT by DKS Associates. Feb 2, 2017

Goal 2: Enable efficient management and operations of the I-90 Corridor

a) Objective: Improve clearance times for all lane-blocking incidents.
b) Objective: Improve construction and maintenance work zone management policy.
c) Objective: Improve coordination between agencies and districts that maintain, operate or respond to incidents or planned events along the facility.
d) Objective: Improve travel time reliability along the corridor.

Goal 3: Enhance traveler information along the I-90 Corridor

a) Objective: Communicate real-time road conditions to travelers using any mode (passenger vehicle, freight, or transit).
b) Objective: Enhance available pre-trip and en-route traveler information.
c) Objective: Provide information about planned events or work zones that impact travel at least 24 hours prior to the occurrence.

For the safety goal, the project team evaluated data from a range of studies that identified the type and degree to which different strategies can reduce crashes. The evaluation focused on safety benefits identified along similar corridors; therefore, if a strategy resulted in a 20 percent decrease in crashes at rural intersections, that benefit would not apply to the I-90 corridor. Two key resources were referenced for these strategies:

- **The ITS Benefit-Cost Database**[2] - This database developed by the ITS Joint Program Office (ITS JPO) of the US Department of Transportation is a searchable database that includes benefit results from specific ITS deployment projects. The reported benefits range from safety related benefits (crash reductions and crash severity), to operational and management related benefits (reduced travel times, reduced incident clearance times, and more).
- **The CMF Clearinghouse**[3] - The crash modification factor clearinghouse includes a compilation of studies that identify how different strategies can reduce crashes. A CMF is a multiplicative factor, that when used in conjunction with a countermeasure, provides the long-term change in expected number of crashes. The studies in the CMF Clearinghouse each have a quality rating between one to five stars, which indicates the confidence of the study results. A quality rating with five stars indicates the highest or most reliable ratings. For the I-90 toolbox, all of the noted CMFs have a quality rating of three or more stars.

For the remaining two goals, the project team evaluated on a qualitative basis how well each strategy aligns with the corridor needs and goals based on what the strategy can achieve.

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[2] Website: http://www.itsbenefits.its.dot.gov/
[3] CMF Clearinghouse website: http://www.cmfclearinghouse.org/index.cfm

The evaluation incorporates the following rating scale:

Icon	Meaning
	Best achieves the project goal
	Mostly achieves project goal
	Achieves some of the project goal
	Achieves little of the project goal
	Does not achieve the project goal

Using the goals as the first level screening criteria, 11 strategies are recommended for further screening as indicated in Table 1. As shown in the table, there are a few strategies recommended for further screening, but as part of another strategy. For example, including the road weather information system (RWIS) stations with the ATM strategy. There are also two strategies (Off-Ramp Traffic Signal Coordination, and Asset Management Software) that should be recognized as ongoing activities that WSDOT will continue to pursue, but separately from this project.

Table 1: Preliminary Screening Based on Project Goals

Strategy	Description	How well does the strategy meet each goal? 1	2	3	Recommend Strategy for Further Screening?
Traffic Operations and Management Strategies					
Active Traffic Management (ATM)	Install devices to create an active traffic management segment that uses a combination of operational strategies that work to fully optimize the existing infrastructure. On I-90 the key ATM strategies include: **variable speed system**, **queue warning system, and dynamic lane control**.				YES
Road Weather Information System Station	Add road weather information system (RWIS) stations along the corridor to relay real-time weather and pavement conditions to travelers.				YES – include with ATM
Ice Warning Signs	Place activated warning signs in key locations that warn travelers when icy roadway conditions are present.				YES – include with ATM
Ramp Metering	Install traffic signals on freeway ramp meters that alternate between red and green signals to control the flow of vehicles entering the freeway. Metering rates can be altered based on freeway and on-ramp traffic conditions.				YES
Ramp Closures (Permanent or Time of Day)	Close an on or off ramp at an interchange to achieve standard interchange spacing and reduce congestion and collisions resulting from substandard interchange spacing.				YES
Integrated Corridor Management	With integrated corridor management, the various institutional partner agencies manage the transportation corridor as a system, rather than the more traditional approach of managing individual assets. Travelers could dynamically shift to alternative transportation options, even during a trip, in response to changing traffic conditions.				YES
Real-Time Traveler Information	Explore options to improve real-time information for travelers including: dynamic message signs (DMS), onboard GPS devices, and 3rd party apps such as Inrix, HERE or WAZE.				YES
Wrong Way Driver Notification System	Install a wrong way driver alert system on off-ramps that can detect wrong way drivers, activate signs to help deter the wrong way driver, and send a notification to the TMC so operators can monitor the car's movement using cameras and send messages to VMS or drivers with on-board systems.				YES
Red Light Running Cameras	Install cameras at select intersections that can automatically detect when a vehicle runs a red light, take a picture, and issue a ticket.				Not at this time

Strategy	Description	How well does the strategy meet each goal? 1	2	3	Recommend Strategy for Further Screening?
	Traffic Operations and Management Strategies (cont.)				
Connected Vehicle Strategy	Implement technologies that relay real-time information from ITS infrastructure to connected vehicles.				Not at this time
Dynamic Curve Speed Warning Signs	Install dynamic feedback signs that measure the speed of individual vehicles and display activated messages if motorist speed is over a designated threshold.				Not at this time
Traffic Surveillance	Add cameras along I-90 to improve traffic monitoring capabilities, and connect to the traffic management center (TMC). This strategy could be used in conjunction with providing real time information for both traveler information and incident management.				YES – include with ATM
Off-Ramp Traffic Signal Coordination	Improve signal timing at select off-ramps and surrounding traffic signals to prevent vehicle queues from extending onto the freeway mainline.				Ongoing
Maintenance and Construction Management Strategies					
Work Zone Management	Address work zone policies and management for both daily (temporary) maintenance activities and longer term construction activities to improve the safety of both the workers and travelers. Strategies include: speed control, use of portable VMS, coordination with law enforcement, communicating delays, detours, and lane configuration changes to travelers.				YES
Telematics Technology on Fleet Vehicles	Add telematics capabilities on fleet vehicles that can be used to track vehicle performance, vehicle maintenance, and vehicle activities in real-time.				YES
Asset Management Software	Install software that enables automated maintenance logs and proactive management of system health (notifications of equipment failure) for ITS infrastructure.				Ongoing – some capabilities included with new ATMS software
Corridor Operations Team	Implement a corridor operations team that coordinates between all agencies that operate roadway facilities or transit along the I-90 corridor.				Not at this time
Transportation Management Center Enhancements	The purpose of a Transportation Management Center is to integrate various departments and offices of transportation and emergency agencies into a unified communications center.				Not at this time

Strategy	Description	How well does the strategy meet each goal?			Recommend Strategy for Further Screening?
		1	2	3	
Emergency and Incident Management Strategies					
Traffic Incident Management Strategies	Pursue TIM strategies that include: **TIM team development**, expanding the **Dedicated Roving Patrol program**, and establishing **instant tow contracts**.				YES
Traffic Incident Management Strategic Plan	Develop a region-specific traffic incident management strategic plan that prioritizes future projects and investments related to traffic incident management. The plan can also help formalize relationships and agreements between responders and agencies.				Not at this time
9-1-1 Dispatch Integration	Connect the 9-1-1 dispatch center with SRTMC. Currently when a call comes into the 9-1-1 dispatch center that effects a state highway, WSP manually calls the TMC to relay the issue. Connecting SRTMC directly to the 9-1-1 dispatch center allows for the transportation agencies to be automatically notified when an event on a state facility occurs. Currently WSDOT has view-only access to events on the WSP computer aided dispatch screen, with some information scrubbed.				YES
Hourly Towing Contract	Initiate an hourly towing contract between WSDOT and towing companies during bad weather conditions or other necessary events. This contract enables WSDOT to dictate towing priorities and allocated towing resources as necessary.				Not at this time
Sharing On-Scene Photos and Video	Invest in technology that allows first responders to send and receive photos and video from an incident scene, including the tow partners.				Not at this time
Interoperable Communication Procedures	Implement standard protocols for using radios between agencies. This strategy could be a task for the TIM Team to develop.				Not at this time
Event Management	Event transportation management systems can help control the impact of congestion at stadiums, convention centers, fairgrounds, or other facilities that generate high traffic volumes for planned events.				Not at this time
Situational Software	Integrate Situational Awareness software during incident or emergency response. The software can track where each of the response agencies/vehicles is (en route, at the scene, and during clean up) and improve communication between responders.				Not at this time

Strategy	Description	How well does the strategy meet each goal? 1	2	3	Recommend Strategy for Further Screening?
Transit and Demand Management Strategies					
Real-Time Transit Information	Provide real-time transit information to transit riders including: vehicle location, estimated arrival time, trip duration, and possibly percent occupancy.				Not at this time
Demand Management Strategies	Promote travel that reduces overall demand on the system such as: bus transit, carpool, and non-peak hour commuting.				Not at this time
Active Demand Management Strategies	Active demand management strategies include using real-time information to dynamically adjust user demand. Strategies include dynamic pricing, on-demand transit, and dynamic ridesharing.				Not at this time
Infrastructure Management Strategies					
Targeted Roadway Improvements	Construct targeted roadway improvements to meet current standards for acceleration and merge areas.				YES
Targeted Shoulder Widening - Auxiliary Lane	Construct shoulder (right or left) to provide an extra travel lane during high demand or high congestion.				Not at this time

SECOND LEVEL SCREENING

For the ten strategies recommended for further evaluation, the project team applied a second level of screening criteria to narrow the strategies to 5 with the best potential to successfully improve safety and operations along the corridor.

Second Level Screening Criteria

The second round of screening focused on four criteria:

- Operational Benefits
- Influencing Factors (Physical Factors, Institutional Factors, Operational and Maintenance Factors)
- Implementation Cost
- Annual Operations and Maintenance Cost

Operational Benefits

Operational benefits include the potential operational benefit of the strategy, and uses results from previously implemented projects and studies documented in the ITS Benefit-Cost Database (discussed in the "First Level Screening Criteria" section). This assessment identifies the level of potential operational benefits for each strategy as it applies to the I-90 corridor.

The project team applied the following ranking system to evaluate each strategy for operational benefits.

Icon	Meaning
	High operational benefits
	Moderate operational benefits
	Some operational benefits
	Limited operational benefits
	Minimal or no operational benefits

Influencing Factors

Influencing factors consider the physical, institutional, and operations and maintenance barriers that may affect the successful implementation of the strategy.

- **Physical Factors** include characteristics necessary to design and build the system such as field devices, central systems, firmware/software, communications, and power connections.

- **Institutional Factors** include characteristics related to the legal, organizational, and behavioral roles associated with operating and managing a transportation system. These include policies, regulations, intra- and inter-agency coordination, and public-private partnerships.
- **Operations and Maintenance Factors** include characteristics related to the processes and procedures needed for day-to-day operation such as agency roles and responsibilities, operating procedures, and performance measurement.

The project team applied the following ranking system to evaluate each strategy by the three feasibility factors independently.

Icon	Meaning
	Minimal or no factors complicating implementation
	Few factors complicating implementation
	Moderate factors complicating implementation
	Several factors complicating implementation
	Not feasible

Implementation and Annual Operations and Maintenance Costs

The costs of implementation and the on-going needs for operating and maintaining a strategy are important criteria to consider when determining whether to pursue a TSMO strategy. These management and operations strategies generally require ongoing staff involvement to make the best use of the strategy and to keep the technology functioning properly.

- **Implementation Cost** – the initial cost to construct a project or create a plan or policy
- **Annual Operations and Maintenance (O&M) Cost** – the ongoing annual cost to maintain and operate devices; fix or calibrate equipment; allocate staff time to implement strategies such as attend meetings or work in the field during a road closure event.

For a strategy to be successful, it is not enough to merely install devices or create a plan, WSDOT needs sufficient resources to support ongoing operations and maintenance of the strategy. Knowing that information before selecting a strategy is critical to success.

The project team applied the following ranking system to evaluate each strategy by implementation cost.

Icon	Implementation Cost
	less than $100,000
	between $100,000 and $500,000
	between $500,000 and $1,000,000
	between $1,000,000 and $5,000,000
	over $5,000,000

The project team applied the following ranking system to evaluate each strategy by annual O&M cost.

Icon	Annual Operations and Maintenance Cost
	less than $1,000 per year
	between $1,000 and $5,000 per year
	between $5,000 and $15,000 per year
	between $15,000 and $50,000 per year
	over $50,000 per year

Strategies Recommended for Advancement

Based on a cumulative evaluation of the first and second level of screening (as shown in Table 2), six strategies are recommended to advance for further evaluation:

- Active Traffic Management
- Ramp Metering
- Ramp Closures
- Wrong Way Driver Notification System
- Traffic Incident Management
- Work Zone Management

Table 2: Strategies Recommended for Advancement

Strategy	First Level Screening			Second Level Screening				Recommend Strategy for Further Study?
	Goal 1: Safety	Goal 2: Efficiency	Goal 3: Traveler Info	Operational Benefits	Influencing Factors[A]	Implementation Cost	Ongoing O&M Cost	
Traffic Operations and Management								
Active Traffic Management – variable speeds, queue warning, dynamic lane control, off-ramp signal coordination	●	●	●	●	○	◉ B	◉	YES
Ramp Metering	●	●	◉	●	◒	◓	◓	YES
Ramp Closures (Permanent or Time of Day)	●	◒	◉	●	◓	◓	●	YES
Integrated Corridor Management	◓	●	○	◒	◒	◓	◓	Not at this time
Expand Real-Time Traveler Information	◓	○	●	○	◒	○	○	Ongoing
Wrong Way Driver Notification System	◒	○	○	◒	●	◓	○	YES
Maintenance and Construction Management								
Work Zone Management	◒	●	○	◒	●	○	◉	YES
Telematics Technology on Fleet Vehicles	◓	◒	○	◓	◒	◒	◓	Not at this time
Emergency and Incident Management								
Traffic Incident Management Strategies – TIM Team Development, Expand Roving Patrol, and Establish Instant Tow Contracts	◒	●	○	●	●	◒	◉	YES
9-1-1 Dispatch Integration	◓	●	○	○	○	○	◒	Not at this time

Strategy	First Level Screening			Second Level Screening				Recommend Strategy for Further Study?
	Goal 1: Safety	Goal 2: Efficiency	Goal 3: Traveler Info	Operational Benefits	Influencing Factors[A]	Implementation Cost	Ongoing O&M Cost	
Transit and Demand Management								
none	--	--	--	--	--	--	--	--
Infrastructure Management								
Targeted Roadway Improvements – Weave and Merge Areas								Not at this time
Notes: A – Four influencing factors: physical, institutional, and operations and maintenance B – The high implementation cost for ATM represents a system wide installation. Smaller segments could be implemented for a lower cost.								

RECOMMENDED STRATEGIES AND LOCATIONS

This section describes the five high priority strategies that are recommended for further study and evaluation. These strategies best meet the project goals, and pass the second level screening to confirm feasibility. In general, these strategies can all work in combination. The one exception is permanent ramp closures, which if implemented, would physically close the ramp and eliminate the merge area. If a ramp is closed on a time-of-day basis, the ramp could also operate ramp metering and the other two strategies.

Active Traffic Management

Active Traffic Management uses a combination of operational strategies to optimize the existing infrastructure and improve safety. On I-90 the primary strategies include a variable speed system, queue warning, travel times, and dynamic lane control. The speed and lane control information would be conveyed to travelers using signs installed over each lane. The system could also provide weather, travel time, and queue warning information to travelers based on real-time measured conditions using full matrix DMS.

Locations

The extent of the active traffic management system should extend between approximately mileposts 277 and 287 in both directions, as shown in Figure 1. In the eastbound direction, installing at least one (possibly two) gantries east of the interchange with US 195 could reduce crashes at the US 195 merge by directing through traffic to use the left lane. Specific locations for speed, lane control, and queue warning signs will be determined in the next analysis phase.

Recommended spacing is approximately 1,500 feet downstream of interchange entrances, or every ½ to 1 mile along an urban freeway system. Specific segments and sign locations will be addressed during the operational concept phase.

Ramp Metering

Traffic signals on freeway ramp meters alternate between red and green to control the flow of vehicles entering the freeway. Metering rates can be altered adaptively based on freeway and on-ramp traffic conditions.

Locations

Ramp metering can either be applied at an individual interchange or corridor-wide. Corridor-wide ramp metering is recommended when[4]:

- Crashes are not clustered at isolated locations, but rather extended along a facility throughout a corridor
- Multiple bottlenecks or locations of recurring congestion are observed

Based on these criteria and existing conditions along the I-90 corridor, ramp metering is recommended on a **corridor-wide** basis. In both the eastbound and westbound directions the potential extents include all the on-ramps from US 195 to the Liberty Lake interchange as shown in Figure 2. The ramp meters could be installed in phases, as indicated by the priorities shown in the figure.

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[4] FHWA. Active Traffic Management Feasibility and Screening Guide. May 2015. Section 5.6

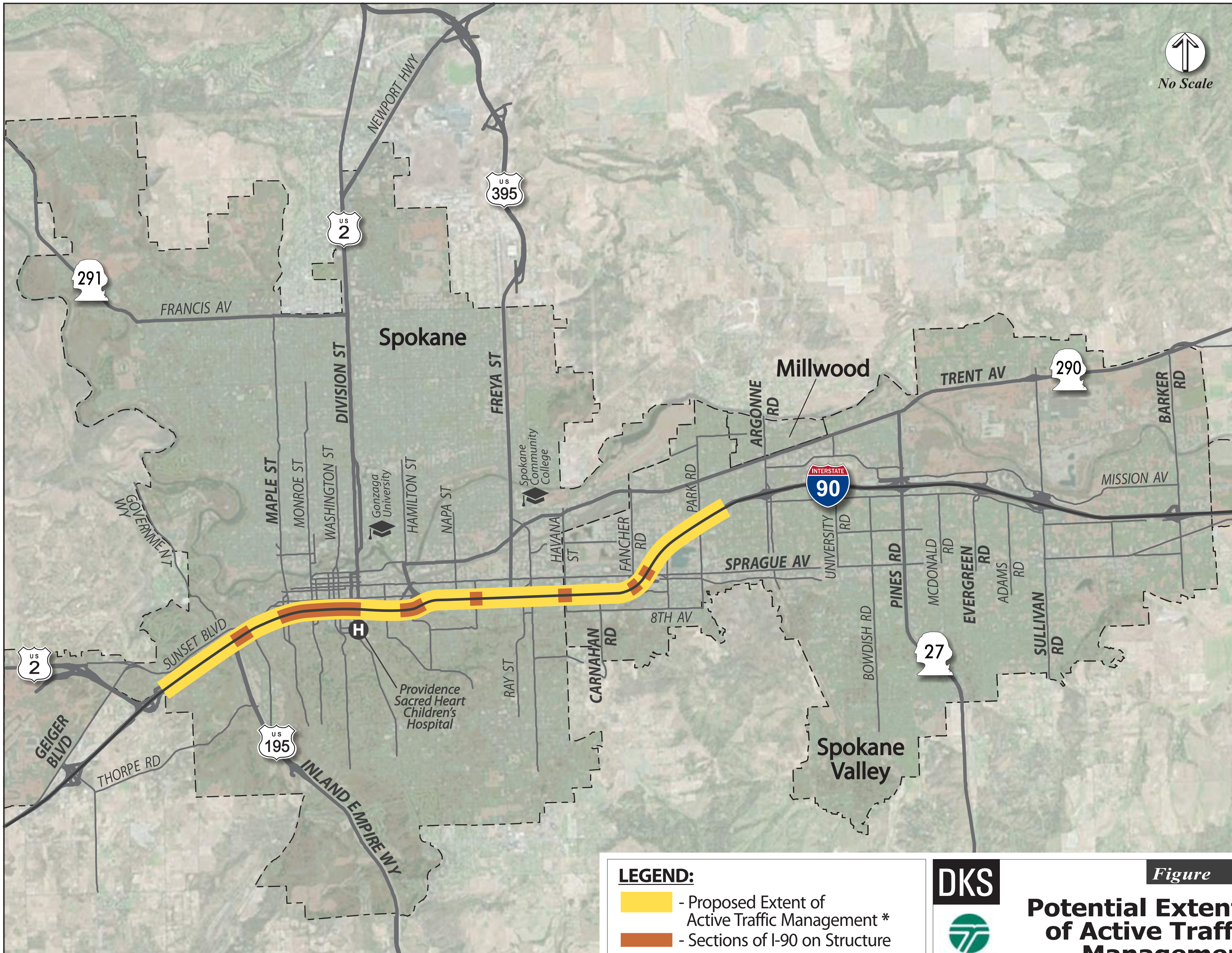
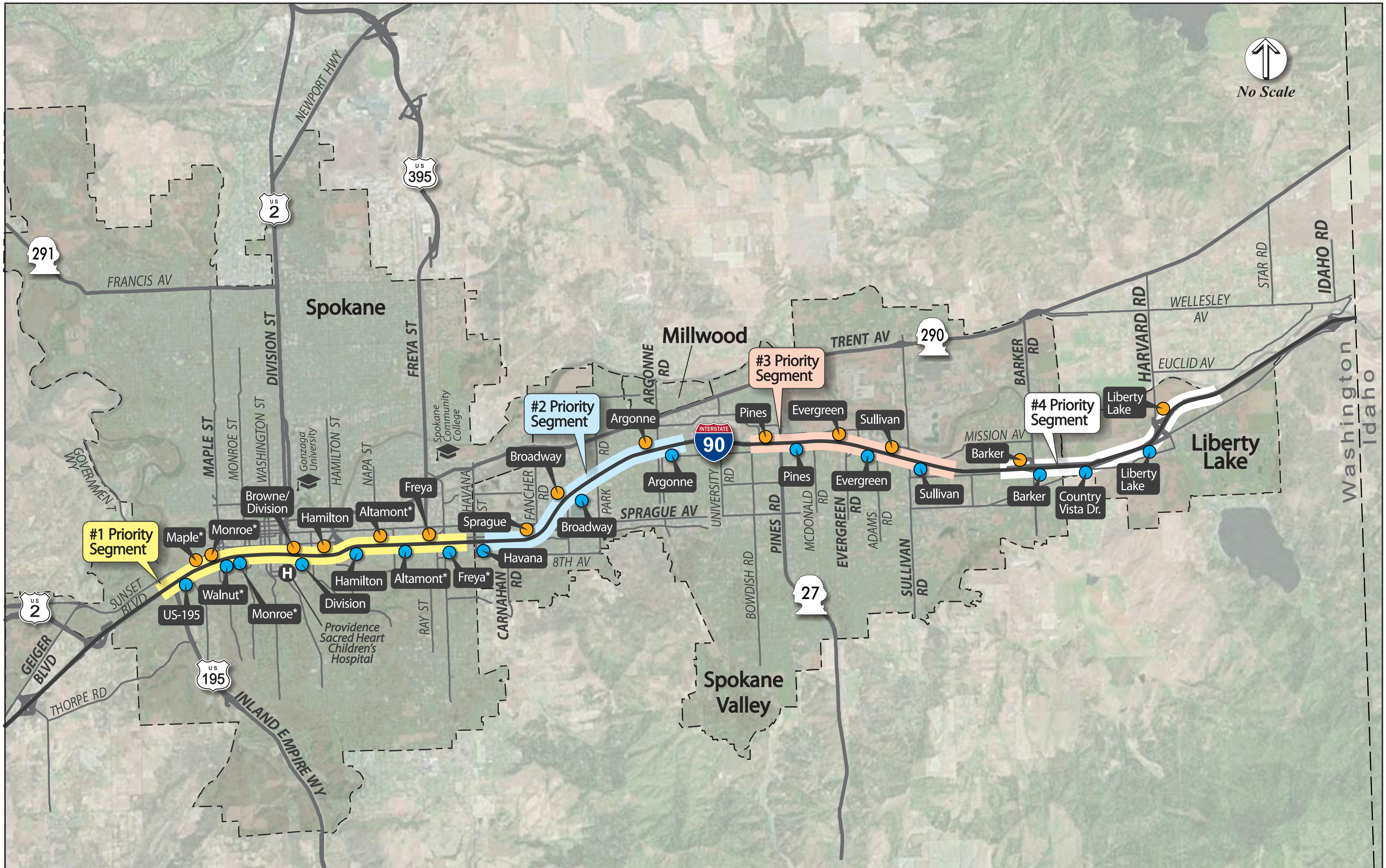


Figure 1

Potential Extents of Active Traffic Management



LEGEND:

- Eastbound On-Ramp
- Westbound On-Ramp

* Ramp is also recommended for further evaluation of ramp closure strategy

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Figure 2

Potential Ramp Meter Locations

Ramp Closures

Closing ramps can improve safety by eliminating hazardous weave and merge areas and by improving interchange spacing to achieve best practices. In general, a ramp closure strategy should only be considered when closing a ramp does not present a more severe problem than already exists. Guidance for ramp closure strategies are outline in the Ramp Management and Control Handbook, published by FHWA.[5]

Ramps can be closed by time-of-day, permanently, or on a temporary basis during specific events. Each type of ramp closure has different advantages and disadvantages, as show in Table 3.

Table 3: Advantages and Disadvantages of Ramp Closure Types

Closure Method	Advantages	Disadvantages
Permanent	• One time cost (no on-going operation cost) • Improves safety and operations permanently	• Impact on existing travel patterns (biggest potential to increase emissions and fuel consumption due to diverted trips) • Potential socio-economic impacts
Temporary (During construction)	• Impacts are temporary • Significantly reduces conflicts during construction or maintenance near the ramp	• Moderate impact on existing travel patterns
Time-of-day	• Closures are restricted to times of day when crashes are likely. Maintains access during all other times of day. • Improves safety and operations during peak hours	• Moderate impact on existing travel patterns • On-going operations and maintenance cost necessary, as well as advanced traveler information signs

Potential Ramp Closure Locations

The locations for potential ramp closures are described below and shown in Figure 3. In addition, ramp volumes are shown in Figure 4 to get a better understanding of the impact a closure may have. Further traffic analysis is necessary before advancing any of the potential ramp closure options. The next phase will analyze and evaluate the traffic impacts of potential ramp closures.

Potential Eastbound Ramp Closures

- Permanent closure of **either** the eastbound **Monroe or Walnut on-ramp**. These two on-ramps are closely spaced and contribute to a high crash frequency (higher than expected based on the predictive crash analysis[6]). Further investigation is necessary to determine traffic diversion impacts, and whether the Monroe or Walnut eastbound on-ramp provides the optimal closure location.

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[5] Ramp Management and Control Handbook. FHWA. January 2006. Chapters 5 and 6.
[6] Existing Conditions Report. I-90 to Idaho State Line Operations Study. March 2017. Prepared for WSDOT by DKS Associates.

- Permanent closure of the eastbound **Freya on-ramp**. Eliminates a short acceleration/merge area and a high crash area. Analysis of this potential ramp closure must consider the current North Spokane Corridor (NSC) Plan, which currently assumes the Freya on-ramp remains open. The next phase of this evaluation will consider the value of a Freya on-ramp closure for safety and operations on I-90 while consider the local access traffic impacts and the NSC plan.
- Time-of-day or permanent closure of the eastbound **Altamont off-ramp**. Eliminates a short weave area between the Hamilton eastbound on-ramp and the Altamont eastbound off-ramp.
- Time-of-day or permanent closure of the eastbound **Altamont on-ramp**. Addresses a short weave area between the Altamont on-ramp and the Freya off-ramp.

Note that if both the eastbound Altamont and Freya on-ramps are closed, traffic can proceed on 3rd Avenue and access I-90 east of Havana Street, an extra 0.5 miles east of Freya or 1.25 miles east of the Altamont on-ramp.

Potential Westbound Ramp Closures

- Permanent closure of westbound **Altamont on-ramp**. Eliminates a short weave segment between the Altamont on-ramp and 2nd Avenue/Hamilton off-ramp.
- Time-of-day or permanent closure of the westbound **Altamont off-ramp**. Eliminates a short weave segment between the westbound Freya on-ramp and the Altamont off-ramp.
- Time-of-day or permanent closure of the westbound **Division off-ramp**. Queues regularly back up onto I-90 during peak commute hours. Option to divert traffic to exit at the 2nd Avenue/Hamilton off-ramp or proceed to the Lincoln off-ramp.
- Time-of-day or permanent closure of **either** the westbound **Monroe or Maple on-ramp**. These two on-ramps are closely spaced and contribute to a high crash frequency (higher than expected based on the predictive crash analysis[6]). Further investigation is necessary to determine traffic diversion impact and whether the Monroe or Maple westbound on-ramp provides the optimal closure location.

Wrong Way Driver Notification System

While wrong way driving incidents are infrequent, accounting for less than one percent of the crashes on I-90, when they do occur the results are severe. Data shows that wrong way collisions have a 12 to 27 times higher fatality rate than other types of crashes. During the five years of crash data analyzed for I-90 there were nine fatalities, three of which were due to wrong way drivers.

The wrong way driver notification system likely applies systematically throughout the I-90 corridor. During the next phase of the project, the project team will evaluate previous wrong way crashes to try to identify whether there are specific off-ramps with repeated problems. However, while crash data identifies the location of the wrong way crash, it may not be possible to trace each wrong way crash to determine from which ramp the wrong way driver accessed the freeway. If specific ramps cannot be identified as repeated problem locations, the strategy should be applied at off-ramps throughout the I-90 study corridor.

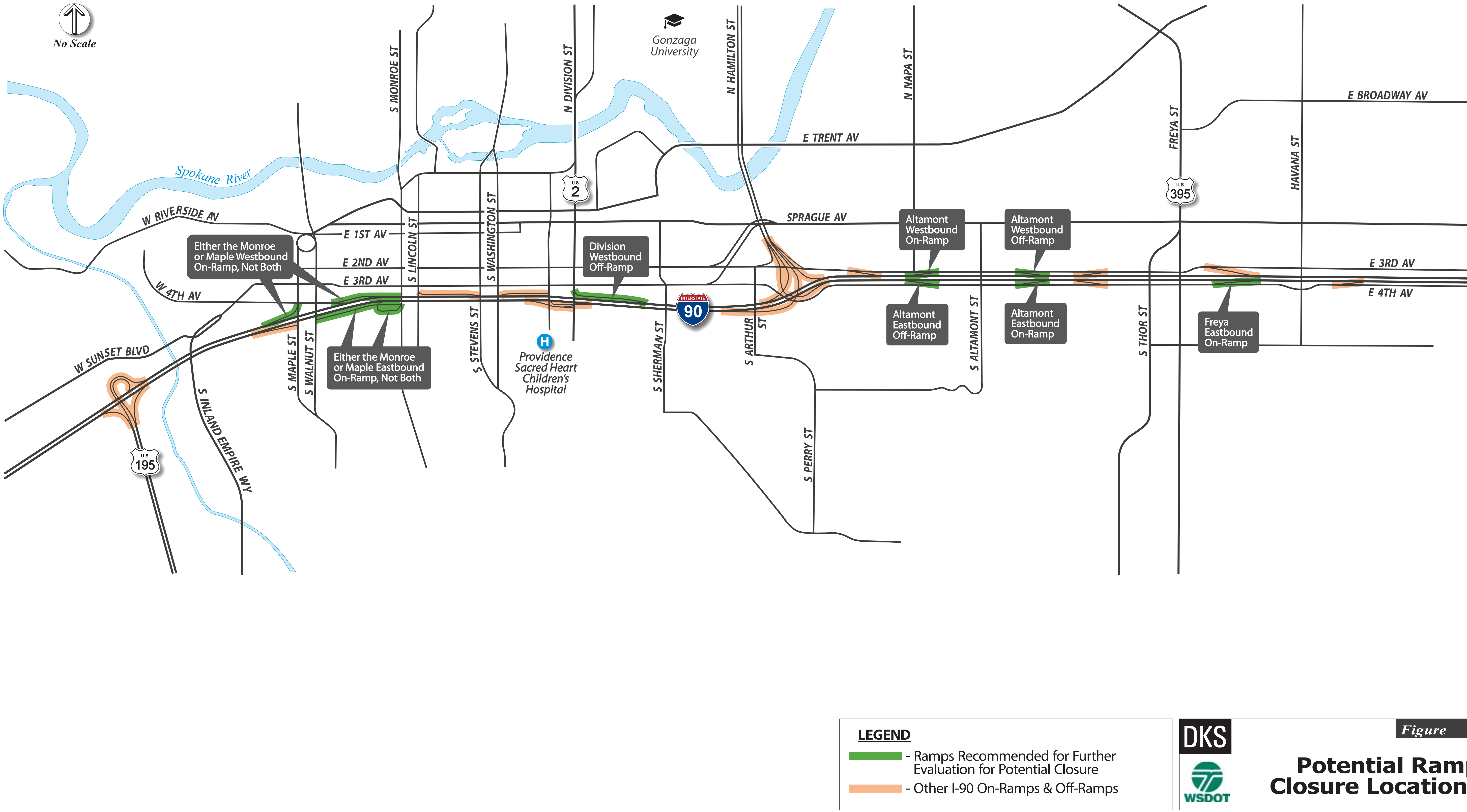

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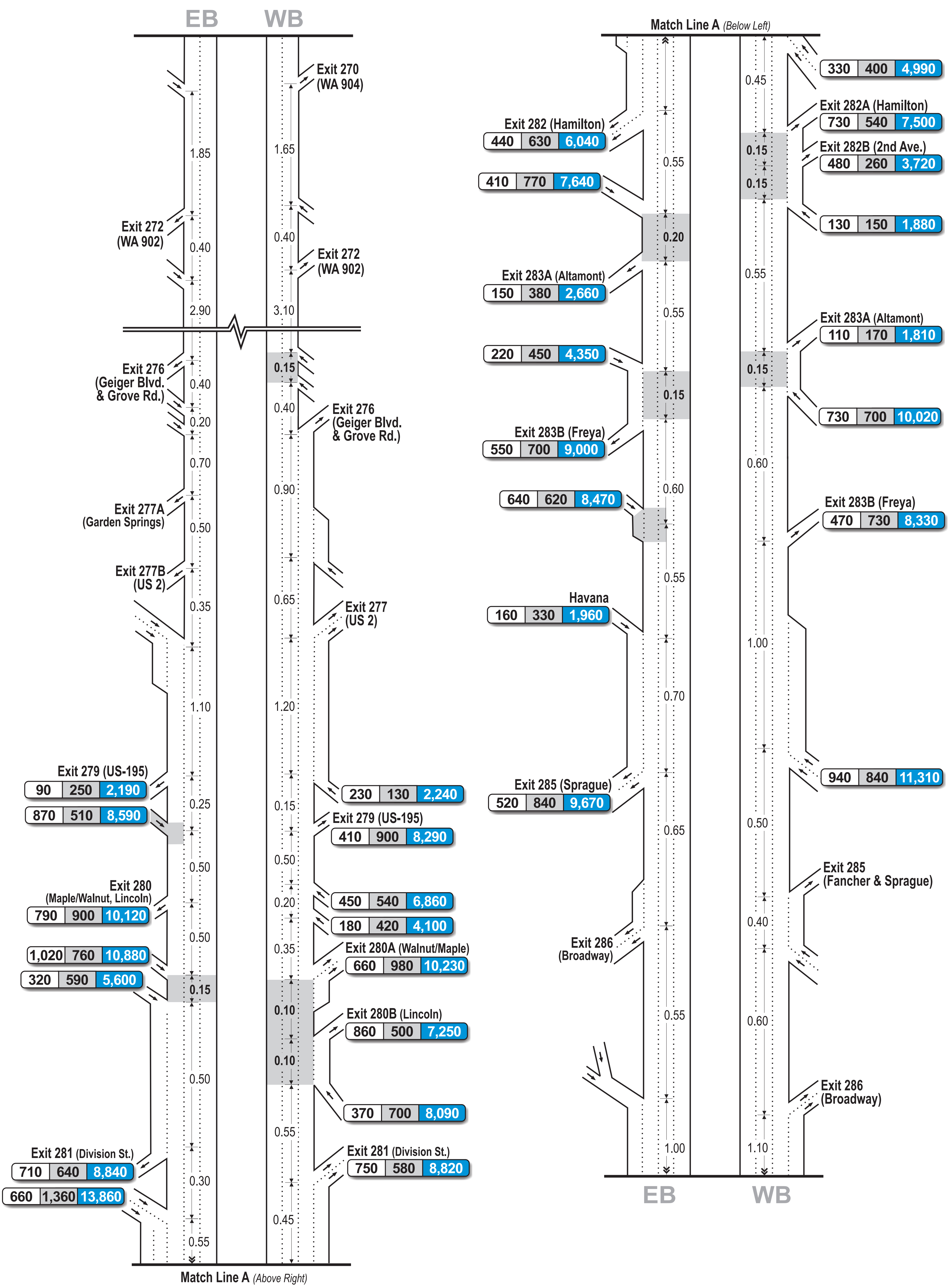
Figure 3

Potential Ramp Closure Locations



NOT TO SCALE

LEGEND

Traffic Volumes - 0,000 (AM) | 0,000 (PM) | 00,000 (ADT)

0.00 - Distance In Miles Between Interchange Gore Areas (Rounded to Nearest 0.05)

0.00 - Merge or Weave Areas That Do Not Meet Current Performance Expectations

Note: AM & PM traffic volumes were measured in June 2015 and averaged across a Tuesday, Wednesday, and Thursday. Seasonal factor & axle adjustments were applied.

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Figure 4

I-90 Lane Geometry & Interchange Spacing

Traffic Incident Management

Traffic incident management systems can reduce the effects of incident-related congestion, reduce secondary crashes, and keep first responders safe, by decreasing the time to detect incidents, the time for responding vehicles to arrive and clear the incident, inform approaching drivers, and provide a safe scene. Ultimately, clearing incidents faster reduces secondary crashes, and the time required for traffic to return to normal conditions. For I-90 the traffic incident management strategies will likely include **developing a traffic incident management (TIM) team** for the region, **expanding the dedicated incident responder program** (called Dedicated Roving Patrols), and **establishing instant tow contracts**.

Location

Traffic incident management should be implemented on a region-wide basis with focus on I-90 and other key state routes.

Work Zone Management

Work zone management includes both long-term stationary construction projects and all other short term maintenance operations including mobile work zones. ITS strategies for work zone management include variable speeds, dynamic lane merging, traveler information providing real-time information about delay and alternate routes, real-time locations of vehicles and workers, real-time locations of lane closures, and automated speed enforcement. Depending on the duration and location of the work zone, different work zone strategies apply. The potential for driverless vehicles further increases the need to digitally share real-time work zone, worker, and vehicle locations so that driverless vehicles safely navigate the temporary and changing conditions within the roadway.

Location

Work zone management strategies should be used for all long-term stationary, short-term temporary, and mobile maintenance operations anywhere within the I-90 corridor.

LESSONS LEARNED FROM PAST IMPLEMENTATIONS

This section presents lessons learned from implementations of the top five strategies in other parts of the country, including the benefits achieved and challenges that had to be overcome.

Active Traffic Management

For I-90, the active traffic management strategy encompasses a combination of variable speed, queue warning, travel times, and dynamic lane control using overhead signs installed on gantries. In cases where the added benefits of dynamic lane control are not warranted, using post-mounted variable speed signs is a lower cost option. However, driver compliance with post-mounted signs may be lower than compared to overhead signs, and experience suggests the post-mounted signs are not as effective. Cases where post-mounted signs might be appropriate include areas where side swipe crashes are not an issue, and where variations in speed are caused by recurring weather conditions. [7]

The following case studies describe benefits and challenges at three different locations:

- In Seattle, Washington[8] an ATM system was installed on I-5, I-90 and SR 520 in 2010 and 2011. The system installed gantries over the freeway at ¼ to ½ mile spacing with variable speed signs, lane control signs, and variable message signs. In total the system covered 23 miles and included 276 signs (multiple signs per gantry). After five years of operations, results on I-5 northbound showed a 4.1 percent crash reduction, while on other similar corridors the region experiences a 2 to 4 percent increase in crashes. Weekend crashes (infrequent drivers) decreased most significantly by 14 percent.

ATM strategies can reduce injury crashes by up to 30%, reduce property damage only crashes by up to 25%, improve throughput and reduce speed variance.

- In Minneapolis, Minnesota[9] the DOT completed an ATM system along 28 miles of freeways by 2012. Results showed a positive impact during the most severe congestion (speeds below 15 mph) and reduced property damage only crashes by 25 percent, a statistically significant amount. However, the annual operations and maintenance cost is about $300,000, plus an additional $60,000 for utilities. Based on the high annual maintenance and operations costs, Minneapolis has taken a more minimal sign approach on future projects.
- In Portland, Oregon[10] an ATM system was installed along OR 217 for 7.5 miles in 2014. The system included variable advisory speed signs, variable message signs, curve and queue warning signs, and adaptive ramp metering. Aside from the ramp meters, most of the components are mounted on gantries that extend over the freeway lanes. Initial results include an 18 percent reduction in crashes, a

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[7] FHWA. Active Traffic Management Feasibility and Screening Guide. May 2015
[8] ATDM Operations and Implementation, WSDOT, Morgan Balogh, April 2015.
[9] Urban Partnership Agreement: Minnesota Evaluation Report, US DOT, FHWA-JPO-13-048, January 2013
[10] Dennis Mitchell. OR 217 Active Traffic Management. ODOT.

9 percent decrease in travel times during the a.m. and p.m. peak commute hours and a 50 percent reduction in travel time variability.

- A group of studies in the US, Germany, Finland, and the UK showed that variable speed systems can reduce overall crashes by up to 15 percent, reduce injury crashes by up to 30 percent, improve throughput by up to seven percent, and reduce speed variance.

Ramp Metering

Ramp metering, when implemented at warranted locations, provides safety and operational benefits that range from improved vehicle throughput and speeds, to reduced crashes in the merge zone and upstream of the merge zone, as well as reduced vehicle emissions and fuel consumption.

The following case studies and results highlight the safety and operational benefits of ramp meters:

- A collection of studies from Minneapolis (MN), Seattle (WA), Denver (CO), Detriot (MI), Portland (OR), Long Island (NY), and Kansas City (KA) all point to a crash reduction ranging from 15 to 64 percent. In Kansas City, a ramp metering system installed at a total of seven interchanges in 2010, reduced the number of crashes attributed to merging by 81 percent.[11]

- A study in Minneapolis showed that when ramp metering was reduced, it resulted increased vehicle emissions, and a seven percent reduction in vehicle speeds. The benefit cost ratio for the Minneapolis-St Paul ramp meter system was 15:1.

- A second simulation study in Minneapolis-St Paul found that ramp metering decreased system travel time by 6 to 16 percent; increased mainline speeds by 13 to 26 percent; and reduced stops on the mainline by 90 percent.[12]

- In Salt Lake City a study showed that with an eight second metering cycle, mainline peak period delay decreased by 36 percent.[13]

For actuated ramp meter systems, expected crash reduction ranges from 20% to 50%, and freeway capacity can increase by 7% to 20%.

One concern in implementing ramp meters is the perception that traffic wanting to access the freeway will divert to local roads to avoid waiting at a ramp meter. In Portland, Oregon, a before and after study observed the impact to traffic volumes on adjacent streets after ramp meters were installed on I-5.[14] The goal was to ensure that the volume increase on local roads did not exceed 25 percent. If so, the ramp meters would need to be adjusted or removed. After the ramp meters were installed, the traffic volume increase on adjacent roads

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[11] Kansas City Scout Program. Ramp Metering Evaluation 2011. Kansas DOT and Missouri DOT. 2012.
[12] ITS database: Evaluation of Ramp Meter Control Effectiveness in Two Twin City Freeways. John Hourdakis and Panos Michalopoulos. January 2002.
[13] ITS database: Utah DOT. March 2004.
[14] Piotrowicz, G. and J. Robinson. Ramp Metering Status in North America; 1995 Update. Publication DOT-T-95-17. Federal Highway Administration (FHWA), U.S. Department of Transportation. June 1995.

was determined "not substantial". Which meant there was little indication that drivers altered their route to avoid the ramp meters.

Ramp Closures

As discussed in the previous section, ramps can close by time-of-day, permanently, or on a temporary basis during specific events.

Permanent Ramp Closures

Permanent ramp closures are infrequent and often face public controversy. There are few examples of permanently closing a ramp, that don't involve construction of a new ramp providing similar access as the closed ramp.

In California, there was once such permanent ramp closure in 2015. In October 2015, California DOT permanently closed an off-ramp in Los Angeles in the direct vicinity of Universal Studios. The closure of the off-ramp from 101 to Barham Road was part of NBCUniversal's Evolution Plan to expand the theme park, which was approved by the LA City Council and LA County Board of Supervisors. The plan included construction of a new on-ramp, which when completed would be too close to the Barham off-ramp, creating weaving and safety issues. In addition, the area suffered from a higher than average collision rate. Based on this information, and acknowledging public concern, Caltrans determined a permanent closure was necessary.

Ramp closures can be a controversial topic. If implemented appropriately, it can decrease crashes and improve freeway throughput.

The closure was not without controversy. An advocacy group filed a lawsuit (which was later dismissed) to keep the ramp open. The lawsuit claimed that Caltrans broke state laws by failing to fully study the potential environmental impacts of the ramp closure and the adverse traffic effects for the surrounding neighborhoods.

Time-of-Day Ramp Closure

Time-of-day ramp closures are not common, but there is some research supporting specific findings. In Detroit, a three-mile section of the John C Lodge Freeway experimented with time-of-day closures and found the following results[15]:

- Freeway volumes increased 3.5 to 13.7 percent.
- Average freeway speed (averages over all periods and locations) increased from 27 to 37 mph in the a.m. peak period and from 25 to 39 mph in the p.m. peak period.

[15] Prevedouros, P.D. H-1 Freeway Ramp Closure: Simulation and Real-world Experiment. Transportation Research Board 78th Annual Meeting. January 1999.

Wrong Way Driver Notification System

Several states including Texas, Rhode Island, and Florida have all installed various wrong way driver notification systems and reported a reduction in wrong way driving incidents following the installations.

- In Texas, a task force identified a section of US-281 near San Antonio as having the largest concentration of wrong way crashes and a pilot study began targeting that section. The pilot study installed radars to detect wrong way drivers and then automatically turn on LED "wrong way" notification signs to warn on coming drivers. After a 14-month pilot study (July 2012 through August 2013) results showed a 30 percent decrease in wrong way driver incidents.[16]

Wrong way driver notification systems can reduce wrong way incidents by 30%

- A system installed at 25 locations in Rhode Island included an early warning system to detect wrong way drivers. During the five years prior to installation 16 crashes were reported, resulting in eight fatalities. In the first 18 months after the system was installed there were zero crashes.[17] The system was activated 66 times, and resulted in the drivers turning around without incident.

Traffic Incident Management

Case studies showing the benefits of implementing traffic incident management programs are abundant. The following list describes a few of the documented benefits:

- In Maryland, the CHART highway incident management system led to almost a 30 percent reduction in average incident duration, which resulted in an estimated 377 fewer secondary incidents. At the time of the report, CHART included: traffic monitoring, incident response, traffic management, and traveler information. [18]
- In Florida, the Miami-Date TIM Team reduced average roadway clearance by 11 percent from the previous year (2008/2009).
- In Georgia, a study determined that when a dedicated incident responder, or Highway Emergency Response Operator (HERO), responded to an incident, the average incident duration was reduced by 69 percent (from 67 minutes to 21 minutes). Other environmental benefits included reduced fuel consumption and emissions.

Dedicated responders can reduce incident duration by 17% to 70%.

- Following a contracted towing strategy that was implemented in Houston, Texas, as part of the SafeClear program, there was a significant reduction in collisions and 90.5 percent of the incidents were cleared in less than 20 minutes. The final evaluation showed that the SafeClear program was responsible

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16 ITS International. Cutting the cost of wrong way driving. May/June 2014
17 Interview with Peter Alviti. Website: http://www.wbur.org/hereandnow/2016/10/27/wrong-way-accidents
18 Performance Evaluation of CHART. Dr. Gang-Len Chang, University of Maryland. November 2003.

for a reduction of approximately 1,440 incidents per year, resulting in an economic savings of $49 million per year.[19]

- In Portland, Oregon, two towing strategies were tested as pilots: instant tow and staged towing. The instant tow decreased tow response times by 30 percent with a minimal annual cost. The study concluded that instant tow dispatch was 50 times cheaper than staged towing. [20]

Work Zone Management

Work zone management has the potential to improve safety for both travelers and workers, and reduce delay through work zones.

- In Northern Virginia along a 7.5-mile stretch of I-495 a variable speed system was implemented to harmonize upstream and downstream traffic around several work zones. Leading up to each work zone were tapered lane closures that reduced travel lanes from four to two or one. The study[21] found that in the case of the four to two lane closure, the VSL produced a mean savings of almost 270 vehicle hours of delay per day (equivalent to about $12,300 per day in user delay savings). When the lane closure went from four lanes to one lane, the VSL did not produce any savings.

- In Washington DC a system posting real-time delay information and a suggestion to use an alternate route during work on I-295 effectively diverted traffic and reduced delay by an average of 52 percent during the construction hours. Using before and after data, the study[22] showed a 3 to 89 percent decrease in mainline volumes.

- In Michigan a dynamic lane merge system was installed on US-131 prior to a construction zone approximately 11 miles long. Based on field observations, the system reduced the number of forced merges seven fold, and reduced the number of dangerous merges three fold.

ITS work zone strategies can reduce crashes, speeds, and traveler delay

- In Oregon in 2010 a section of US 30 in the Portland area was under construction. A photo radar enforcement van was stationed at the work zone temporarily during construction. While the van was stationed at the work zone, speeding was reduced by an average of 23.7 percent. After the van departed, the speed reduction did not continue. [23]

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19 Best Practices in Traffic Incident Management. FHWA. 2010.
20 Tow Truck Response Strategy Evaluation. Prepared for ODOT by Kittelson and Associates. November 2012.
21 Fudala, Nicholas J., Michael Fontaine. Work Zone Variable Speed Limit Systems: Effectiveness and System Design Issues. Virginia Department Research Council. Final Report VTRC 10-R20. March 2010.
22 FHWA Comparative Analysis Report: The Benefits of Using Intelligent Transportation System Work Zones. Report Number FHWA-HOP-09-002. October 2008.
23 Joerger, Mark. Photo Radar Speed Enforcement in a State Highway Work Zone: Demonstration Project Yeon Avenue – Final Report. ODOT. April 2010.

- In Illinois in 2011, portable variable message signs were used to warn motorists about vehicle queues well in advance of a work zone at the I-79/I-57 interchange in Effingham. Portable VMS were located 10 to 12 miles upstream of the work zone, providing drivers with information about the work zone and opportunities about alternate routes. Reviewing the before and after data, researchers found that the system reduced queueing crashes by 14 percent, and reduced injury crashes by 11 percent, despite a 52 percent increase in the number of days when temporary lane closures were implanted during the evaluation.

As part of the studies mentioned above, key lessons learned were identified in the FHWA Comparative Analysis Report:

- Coordinate with neighboring agencies
- Allow time for obtaining right of way use permits to place equipment (portable VMS)
- In the design of ITS for work zone applications, involve the construction contractor as early as possible
- Ensure that the managing agency has real-time access to archived system data

NEXT STEPS

During the next phase of the project, more detailed analysis of each of the recommended strategies will be conducted to assess the potential effectiveness of the strategies, consider challenges, impacts, and costs.

The project team will include the following elements for each strategy in the Implementation Plan:

- Provide an overview of the system
- Refine the project costs and benefits
- Create a map indicating locations for the proposed field equipment
- Identify resources and partnerships necessary for successful operations of each strategy
- Refine cost estimates to show design, construction, and annual operations and maintenance costs
- Describe system software enhancements if necessary
- Develop a phased implementation plan

Attachment A

Toolbox of Strategies

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Traffic Operations and Management				
Active Traffic Management **(Includes: Variable Speed System, Queue Warning, Dynamic Lane Control, added surveillance)**	Active traffic management consists of a combination of operational strategies that, when implemented in concert, fully optimize the existing infrastructure and provide measurable benefits to the transportation network and the motoring public. The strategies would all use variable message signs mounted on gantries over the travel lanes. On I-90 the strategies include: **Variable Speed System -** enables adjustments to the posted speed (regulatory or advisory) based on real time congestion and weather conditions. If weather conditions are incorporated, **RWIS stations** are necessary. The primary purpose of a variable speed system is to provide better information about current conditions and reduce crashes. The variable speeds would be displayed on dynamic message signs on overhead gantries with the potential for a dynamic message sign over each lane. **Queue Warning System** - the overhead dynamic message signs could also display messages that alert drivers about downstream slowing so that drivers are aware of an upcoming change in speed due to unexpected congestion. **Dynamic Lane Control -** using dynamic signs over lanes, enables operators to close lanes or shift traffic to improve safety and operations during a variety of scenarios (closing a lane in advance of a high volume on-ramp that requires an extra lane, closing a lane and merging traffic in advance of an incident that blocked a lane, other special events).	Reduces crashes - VSL can reduce crashes by 8% (CMF ID: 3340). In particular VSL can target rear-end crashes. - Queue Warning can reduce injury crashes by 16% to 44% (CMF ID: 75 and 76) - Reduces fixed object and side-swipe crashes - Reduces weather related crashes Improves Commuter Mobility: - Makes travel times more reliable during peak hours	Cost ranges depending on corridor length, sign type, sign frequency, and available utilities. Range $5,000,000 to $10,000,000 for a 20 mile urban segment. Typical cost for each gantry installation is approximately $500,000. Based on past project in Seattle, Portland, and the Bay Area, the average cost per lane mile of an ATM System is $500,000	Physical Factors - Available ROW for sign structures; structural sections of I-90 may be challenging to construct gantries; connection to utilities and communications network; maintenance access; integration of various ITS components. Institutional Factors - Coordination with local law enforcement. Public perception and potential resistance. Public education necessary; train staff to operate new system. Operational and Maintenance Factors - Ensure detection is accurate and maintained providing real-time data; ongoing operations and maintenance requirements; developing procedures for system failures; understand technical capabilities and limitations of equipment; periodic software updates.
Road Weather Information Systems/Weather Responsive Systems **Note - option to include with ATM System**	Install Road Weather Information Systems (RWIS) with ice detection at key locations. Surveillance, monitoring, and prediction of weather and roadway conditions enable the appropriate management actions to mitigate the impacts of any adverse conditions. Install sensors that detect conditions such as pavement grip factor and visibility. Then use the information to alert travelers of hazardous conditions either via electronic roadside signs or other means. This strategy can also be used to manage a variable speed system.	- Travelers perceive enhanced safety by being better prepared for roadway conditions - Lower traveler frustrations due to better real-time information - Expected B:C ratios 2:1 to 10:1 - Improved weather information leads to more efficient application of anti-icing chemicals, reduced maintenance costs, reduced delay, and increases safety (US DOT) - Improved safety by reducing crashes - Reduced vehicle speed during adverse weather - Improved information for agency decision-makers and travelers - Reduces weather related crashes	Cost varies which can range from $20,000 for a sensor unit to over $3 million for a weather management system. Weather station ($20-50k capital, $1.5-4k operations and maintenance), CCTV-surveillance ($25k-40k capital, $1.0k-2.5k operations and maintenance), Highway Advisory Radio ($16-32k capital, $500-1,000 operations and maintenance), variable message signs ($50k-120k capital, $2.5k-6k operations and maintenance), and variable speed limit display ($3-5k capital).	Physical Factors - Available ROW for RWIS structures, connection to utilities and communications network; maintenance access; integration of various ITS components. Institutional Factors - Optimize operations by interagency cooperation between weather systems. Operational and Maintenance Factors - Ensure RWIS sensors are accurate and maintained providing real-time data; ongoing operations and maintenance requirements; understand technical capabilities and limitations of equipment; periodic software updates.
Ice Warning Signs **Note - option to include with ATM System**	Install activated ice warning signs at key locations that notify drivers (via VMS, flashing beacons, or other means) when roadway conditions are icy. For optimal benefit, detection segments should be short and warning systems frequent. Ice detection could use an existing or proposed RWIS station, or a grip factor sensor at the sign location.	- Ice Curve Warning System reduced ice-related crashes by 18% (CMF ID: 4114, 2 star)	$5,000 to $45,000 (cost does NOT include power or communications) $5,000 annual operations and maintenance cost	Physical Factors - Available ROW for sign structures; connection to utilities and communications network; maintenance access; integration of various ITS components. Institutional Factors - Educate travelers; liability concerns if a crash occurs during a sign failure; train staff to operate new system. Operational and Maintenance Factors - Ensure signs and sensors are accurate and maintained providing real-time activated warning messages; developing procedures for system failures; ongoing operations and maintenance requirements; understand technical capabilities and limitations of equipment; periodic software updates.

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Ramp Metering	Traffic signals on freeway ramp meters alternate between red and green signals to control the flow of vehicles entering the freeway. Metering rates can be altered based on freeway and on-ramp traffic conditions.	Reduces crashes - Reduces crashes by 36% on roadways with 50K to 200K AADT (CMF ID: 5436) Reduces mainline peak period delay - Increases freeway speed - Improves freeway capacity - Reduced duration of congestion - Reduces mainline stops	$25,000 - $66,000 per site; $6,500 for detection components per site; $1,000-$3,000 per site for annual operation and maintenance	Physical Factors - Ensure infrastructure and timing plans allow green time to meet demand. Avoid queue spillback to adjacent intersections. Institutional Factors - Agency coordination on operations to ensure ramp queues don't impact surface street operations; public perception that ramp meters may increase delay accessing freeway and potential resistance Operational and Maintenance Factors - Ongoing operations and maintenance requirements.
Ramp Closures (Permanent or Time of Day)	Close an on or off ramp at an interchange to achieve standard interchange spacing and reduce congestion and collisions resulting from substandard interchange spacing.	- Improves safety - Reduces fixed object and side-swipe crashes - Increases freeway vehicle throughput and speeds - Improves commuter mobility - Makes travel time more reliable during peak hours - Reduces non-recurring delay for planned events - Improves freight mobility - Makes travel time more reliable during non-peak hours	Highly variable.	Physical Factors - ROW necessary for infrastructure connections and enhancements to combine ramps or physically close ramps. Support diverted traffic. Institutional Factors - Public perception and potential resistance. Creates confusion to travelers if closures are by time of day; potential to move congestion to surface streets. Operational and Maintenance Factors - Ongoing O&M required. Need to providing adequate traveler information in the short term about route change. If time of day closures are implemented, an advance traveler information system would be necessary.
Integrated Corridor Management	With integrated corridor management, the various institutional partner agencies manage the transportation corridor as a system, rather than the more traditional approach of managing individual assets. Travelers could receive information that encompasses the entire transportation network including parallel facilities that may provide faster travel times. They could dynamically shift to alternative transportation options, even during a trip, in response to changing traffic conditions.	- Reduced travel time and delays - Increased reliability and predictability of travel	$2,000 - $3,000 per intersection for signal retiming (additional cost if new detection is necessary). Approximately $500,000 per variable message sign (includes sign, support, controller, and installation) Annual O&M dependent on which strategies are installed.	Physical Factors - utilizing existing ITS devices and communications; expanding communications. Institutional Factors = Interagency cooperation and implementation is key to project success. Operational and Maintenance Factors - staff training; on-going O&M to ensure field devices and communications are properly functioning.
Expand Real-Time Traveler Information	Advanced communications have improved the dissemination of information to the traveling public. Motorists are now able to receive relevant information on location-specific traffic conditions in a number of ways, including dynamic message signs (DMS), onboard GPS devices, and 3rd party apps such as Inrix, HERE or WAZE. May include 511 systems. Provide predictive travel times using algorithms that combine existing data with future weather/event information.	- Reduced delay and number of stops - Reduced gas emissions Improves Commuter Mobility: - Makes travel times more reliable during peak hours - Reduces non-recurring delay for planned events Improves Freight Mobility: - Makes travel times more reliable during peak hours - Makes travel times more reliable during non-peak hours	Cost per VMS installation approximately $500,000 which includes the sign, support, foundation, controller, and installation. Typical O&M cost of 3% of installation cost. Other methods such as partnerships with private information service providers will have variable costs.	Physical Factors - Constantly evolving technology. Institutional Factors = Agency partnership and data/resource sharing to create a robust system; educating the public and explaining the benefits of an ITS solution versus expanding roadway infrastructure. Operational and Maintenance Factors - staff training and ongoing O&M to ensure field devices are functioning and accurate.
Connected Vehicle Strategy	Deliver real-time roadway information to connected vehicles. Ensure that roadway related communications systems are connected vehicle ready. Delivery of roadside infrastructure information to vehicles may use a combination of cellular networks and short range communication radios dedicated for connected vehicles. When implementing new roadside devices, Agency should support sharing standard message sets from roadside devices such as DMS through a central application programming interface (API) or including extra conduit and pole capacity to accommodate roadside dedicated short range communications (DSRC) radios. The system could deliver road conditions, current speeds, incident notification from the roadside to the vehicle.	- Improves safety - Improves commuter mobility - Improves freight mobility - Reduces rear end crashes - Reduces fixed object and side-swipe crashes - Reduces weather related crashes - Makes travel times more reliable during peak hours - Makes travel times more reliable during non-peak hours - Reduces freight related crashes	variable	Physical Factors - Available room in device cabinets and conduit; quickly evolving technology is changing quickly. Institutional Factors - Sharing resources across agencies and creating public-private partnerships; education of public; understanding what connected vehicle readiness means. Operational and Maintenance Factors - educating staff about policy

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Increase Traffic Surveillance	Monitor traffic operations in real-time using video cameras along the corridor that are controlled from a traffic management center (TMC). This strategy could be used in conjunction with providing real time information for both traveler information and incident management.	- Improved incident response times and accuracy - Real-time and historic system operations information - Improved visual information for decision-makers and the public - Clears lane blocking incidents faster - Makes travel time more reliable during peak hours - Makes travel time more reliable during non-peak hours	$25,000 - $40,000 per CCTV (camera + pole) detection unit, $1 - 2 million for central system integration and firmware upgrade if run through a TMC	Physical Factors - Connection to utilities and communications network; determining communication requirements if live streaming and pan tilt zoom capabilities are necessary; integration of various ITS components Institutional Factors - Public perception of "big brother" surveillance and invasion of privacy; establish policies to share images with other agencies. Operational and Maintenance Factors - Ensure cameras are maintained providing real-time images; ongoing operations and maintenance requirements.
Dynamic Curve Speed Warning Signs	Dynamic feedback signs can measure the speed of individual vehicles and post messages such as "SLOW DOWN. YOUR SPEED IS OVER 60 MPH. CURVE AHEAD" Note - if an Active Traffic Management System is installed, this component could be incorporated.	- Crash reduction of 2% to 50% for beacons (CMF Clearinghouse) - Speed reduction in 68% of drivers (rural CA, 2000) - Ice Curve Warning System reduced ice-related crashes by 18% (CMF ID: 4114, 2 star)	$15,000 (basic sign with beacons) $100,000+ (overhead mounted feedback message sign)	Physical Factors - Available ROW for sign structures; connection to utilities and communications network; maintenance access; integration of various ITS components; determining criteria that activates the warning. Institutional Factors - Educate travelers; liability concerns if a crash occurs during a sign failure; potential for non-compliance. Operational and Maintenance Factors - Ensure signs and sensors are accurate and maintained providing real-time activated warning messages; developing procedures for system failures; ongoing operations and maintenance requirements; understand technical capabilities and limitations of equipment; periodic software updates; train staff to operate new system.
Off-Ramp Traffic Signal Coordination (Mainline Vehicle Queue Prevention)	Improve signal timing at select off-ramps and surrounding traffic signals to prevent vehicle queues from extending onto the freeway mainline.	Improves Safety: - Reduce queues on mainline and resulting rear end crashes	$4,000 - $7,000 per intersection for signal retiming and ramp detection. Cost increases if new traffic signal controller or other intersection improvements are necessary.	Physical Factors - Reliable and accurate vehicle detection must be maintained. Institutional Factors - Coordinating between multiple agencies Operational and Maintenance Factors - ongoing retiming and coordination
Wrong Way Driver Notification System	Install a wrong way driver alert system on off-ramps that can detect wrong way drivers, activate signs to help deter the wrong way driver, send a notification to the TMC, and automate messages to VMS or on-board systems to notify drivers.	- Reduce fatal and severe injury crashes - TxDOT implemented a wrong way driver notification system which decrease wrong way events up to 30% - ITS Database	Approximately $25,000 to $150,000 per off-ramp depending on the extent of new detection and activated signs. Additional VMS approximately $300,000 each. Low end includes activated "wrong way" signs to notify the wrong way driver. Higher cost includes those signs plus a system to notify on-coming traffic, law enforcement, and traffic operation centers.	Physical Factors - Communication between ITS devices, locating equipment. Institutional Factors - Coordinating with WSP. Operational and Maintenance Factors - Ongoing O&M required; detection accuracy critical.
Red Light Running Cameras	Install cameras at select intersections that can automatically detect when a vehicle runs a red light, take a picture, and issue a ticket.	- Reduce fatal red light running crashes by 24% - ITS Database - Reduce all fatal crashes at signalized intersections by 17% - ITS Database	Approximately $70,000 to $90,000 which includes: camera, detectors, and related wiring and housing.	Physical Factors - Placement of equipment in ROW. Institutional Factors - Public acceptance; coordination with local agency depending on who owns, operates, and maintains the traffic signal. Operational and Maintenance Factors - Ongoing O&M and calibration required.

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Maintenance and Construction Management				
Work Zone Management **(Includes both construction long term work zone management and daily maintenance work zone activities)**	Implement work zone management strategies to reduce the duration of the construction activity and safety impacts to travelers and workers. ITS applications in work zones include the temporary implementation of traffic management such as variable speeds, automated enforcement, portable VMS to control lane use in advance of the work zone, as well as other applications. Other management strategies may include limiting lane closures during daytime hours, incentivizing contractors to reduce the duration of the activity, and using demand management programs to reduce traffic volumes through work zones.	- Reduced traveling speed across work zone by 9mph and reduced speed variability by 70% in a Minneapolis/St. Paul study - Improved safety with reduced travel speed - Reduced delay and travel time - Using portable VMS: - driver speeds reduced by 3.6 mph upstream of work zones (study in rural Missouri) - When used in conjunction with radar, a study in Virginia found a 50% reduction in speeding vehicles through work zones, with a decrease in vehicle speeds of up to 9 mph within a work zone	$150 - 800k for a work zone management system, which commonly includes variable message signs ($50k-120k capital, $2.5k-6k operations and maintenance), CCTV-surveillance ($25k-40k capital, $1.0k-2.5k operations and maintenance), Highway Advisory Radio ($16-32k capital, $500-1,000 operations and maintenance), traffic detectors ($3k-13k capital, $100-1,000 operations and maintenance) and variable speed limit display (varies, $75k+ for full matrix with controller, less for LED panel within regular speed sign), etc. Costs are dependent on agency leasing or purchasing, and portable versus permanent components.	Physical Factors - Available ROW to set up system and provide through movement for travelers. Institutional Factors - Coordinating across agencies and with the WSP for enforcement; public outreach and education Operational and Maintenance Factors - Staff training
Telematics Technology on Fleet Vehicles	Telematics capabilities that can be used to track vehicle performance and vehicle maintenance. Telematics technology has a range of capabilities. For maintenance vehicles some of the key features to implement are tracking performance and fuel use, automatic notifications when vehicle maintenance is necessary, and improve routing efficiency.	- Reduces fuel costs - Improves vehicle maintenance - Reduces idle time	$5,000 to $15,000 per vehicle (assumes some retrofitting necessary). If implemented with AVL there are cost savings $1,000 per vehicle annual operations and maintenance cost	Physical Factors - Ensure vehicles are properly equipped; establish communications system to collect and process the data. Institutional Factors - Fleet operators may be hesitant to track all activity and locations; coordination across agencies. Operational and Maintenance Factors - Regular software updates and device maintenance; staff training.
Asset Management Tool	Install software that enables automated maintenance logs and proactive management of system health (notifications of equipment failure) for ITS infrastructure: • Traffic signal controllers • Street lights • Cameras • VMS • RWIS	- Improves operational efficiency	Varies based on system	Physical Factors = Determining the optimal software platform and integrating all ITS components Institutional Factors - Implementation could be more of a statewide initiative than a regional approach. Operational and Maintenance Factors - staff training and regular software updates.
Corridor Operations Team	Implement a corridor operations team that meets regularly to coordinate operations within the corridor. Specific activities the corridor operations team could be responsible for could include: Planning management and operations (M&O) for special events, coordinate incident response, review performance, allocate resources for active corridor operations.	- Improves safety - Clears lane blocking incidents faster - Improves commuter mobility - Makes travel times more reliable during peak hours - Reduces non-recurring delay for planned events - Improves freight mobility - Makes travel times more reliable during peak hours	Cost is mostly staff time (variable)	Physical Factors = Providing communication between agencies Institutional Factors - Coordinating between agencies and creating dedicated staff roles. Operational and Maintenance Factors - staff time.
Transportation Management Center Enhancements	The purpose of a Transportation Management Center is to integrate various departments and offices of transportation and emergency agencies into a unified communications center. The integration provides the communications and computer infrastructure necessary for coordinated transportation management on roadways during normal commuting periods, as well as during special events and major incidents.	- More efficient coordination and operation of various transportation systems - Better data collection for decision-making and future planning purposes - Co-locate and collaborate with traffic, transit, fire, emergency, police, etc.	Varies depending on specific enhancements.	Physical Factors - Available space at TMC for expansion or additional communication connections. Institutional Factors - Communication and interoperability issues may exist among agencies. Changing agency culture to operate differently. Potential collaboration with transportation, emergency, police, fire, etc. Operational and Maintenance Factors - added staff time and training

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Emergency and Incident Management				
Traffic Incident Management Strategies **(Includes TIM Team Development and Dedicated Incident Responders and Instant Towing)**	Incident management systems and planning reduce the effects of incident-related congestion by decreasing the time to detect incidents, the time for responding vehicles to arrive, and the time required for traffic to return to normal conditions. Incident management systems make use of a variety of surveillance technologies as well as enhanced communications and other technologies that facilitate coordinated response to incidents. Other incident response element include: **- TIM Team Developmen**t - develop and operate a TIM team for the Spokane region that includes responders from DOT, Fire, Tow, Law Enforcement, County, Cities, and 911 dispatch. Establish regular meetings and communication with the TIM Team. **- Dedicated Incident Response Vehicles** - expanding the current Dedicated Roving Patrol program, especially during peak travel periods to assist disabled vehicles, respond to incidents and reduce clearance times. **- Establishing Instant Tow Contracts** - the purpose of instant tow contracts is to deploy a tow truck to a scene as soon as the incident is reported, rather than waiting for on-scene confirmation. This strategy can greatly reduce clearance times and secondary crashes.	- Reduced average incident duration (studies cite a range of 10% up to 70% reduction in incident durations) - Decreased secondary crashes - Reduced delay due to quicker incident clearance - Improve coordination between responder partners - Improve understanding of partner roles	Variable - Cost dependent on which strategies are implemented: TIM Team - cost is mostly staff time Dedicated Roving Patrol program - estimate $55 per vehicle hour for patrolling vehicle plus cost of additional vehicles if necessary. Instant Tow Contracts - variable	Physical Factors - Reliable communication system with wide coverage; interoperability issue among different agencies Institutional Factors - Coordination between multiple responder agencies. WSDOT already has a Dedicated Roving Patrol on staff. Operational and Maintenance Factors - staff time and training.
Traffic Incident Management (TIM) Strategic Plan	Develop a region specific traffic incident management strategic plan that prioritizes future projects and investments related to traffic incident management. The plan can also help formalize relationships and agreements between responders and agencies.	- Improve coordination between responder partners - Improve understanding of partner roles - Improve management's understanding of TIM roles and responsibilities	Staff time to prepare plan. If developed by a consultant, estimated cost is $100,000	Physical Factors - n/a Institutional Factors - Coordination between multiple responder agencies. Operational and Maintenance Factors - staff time to maintain and update plan.
9-1-1 Dispatch Integration	Connect the 9-1-1 dispatch center with SRTMC. Currently when a call comes into the 9-1-1 dispatch center that effects a state highway, WSP manually calls the TMC to relay the issue. Connecting SRTMC directly to the 9-1-1 dispatch center allows for the transportation agencies to be automatically notified when an event on a state facility occurs. Currently WSDOT has view-only access to events on the WSP computer aided dispatch screen, with some information scrubbed.	- Reduce incident response time - Shorten incident duration - Reduce dispatch response time - Reduce interagency calls Results from Deschutes County in Oregon: - reduced interagency calls by 60% - reduced response time by 25 minutes		Physical Factors - communication links between WSDOT, WSP, and other local agencies. Institutional Factors - Coordinating between multiple agencies; processing sensitive information. Operational and Maintenance Factors - staff time; staff training; periodic software updates.
Hourly Towing Contract (during severe weather or specific events)	Initiate an hourly towing contract between DOT and towing companies during bad weather conditions or other necessary events. This contract enables DOT to dictate towing priorities and allocated towing resources as necessary.	- Improves safety - Reduces rear end crashes - Reduces fixed object and side-swipe crashes - Clears lane blocking incidents faster - Improves commuter mobility - Makes travel times more reliable during peak hours - Improves freight mobility - Makes travel times more reliable during non-peak hours - Reduces freight related crashes	Variable	Physical Factors - Communication interface with tow companies Institutional Factors - Developing a contract and partnerships between DOT and tow companies. Operational and Maintenance Factors - On-going verification that tow companies are in compliance with WSDOT standards

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Sharing On-Scene Photos and Video	Invest in technology that allows first responders to send and receive photos and video from an incident scene, including the tow partners.	- Increase the percent of time tow companies arrive with correct equipment - Faster incident clearance	$200 to $1,000 per vehicle	Technical Factors - Implemented software that operates on current responder vehicles or systems. Institutional Factors = Developing protocol for sending photos and video with sensitive information; perception that media may be shared inappropriately; privacy concerns. Operational and Maintenance Factors - staff training and education about sending sensitive images.
Interoperable Communication Procedures	Implement standard protocols for using radios between agencies. This strategy could be a task for the TIM Team to develop.	- Faster incident clearance, gets responders to the scene and where they are needed at the scene faster - Improve on-scene communication	Staff time to prepare protocol and provide training. Ongoing staff time for training and updating	Physical Factors - Selecting communication technology and software. Institutional Factors - Coordination across multiple agencies. Operational and Maintenance Factors - staff training and periodic software updates.
Event Management	Event transportation management systems can help control the impact of congestion at stadiums or convention centers. In areas with frequent events, large changeable destination signs or other lane control equipment can be installed. In areas with occasional or one-time events, portable equipment can help smooth traffic flow.	- Reduced delay amidst heavy demand during special events - Reduced crash rates due to reduced conflicts - Increased attractiveness of event attendance, particularly repeat attendees	(System components are similar to Incident Management, which gives similar cost as that) $2,000 - $3,000 per intersection for specialized event timing plan; $20-$50 per hour per officer for manual traffic control; $2,000 - $3,000 per lane control display; $300K - $450K per lane control system including software, integration and other hardware costs	Physical Factors - Available ROW to place equipment; available power and communications to equipment; Institutional Factors - Coordination with various event organizers and agencies; concern from residents about detours through local roadways. Operational and Maintenance Factors - maintaining a current contact list for event sites and agencies; developing procedures; ensuring detour routes have adequate capacity.
Situational Software	Integrate the Situational Awareness, such as Intterra, software during incident or emergency response. The software can track where each of the response agencies/vehicles is (en route, at the scene, and during clean up) and improve communication between responders.	- Faster incident clearance - Improve on-scene communication - Improve incident scene management	Annual license fee (based on a system used by Keno Fire Dept. in Oregon the annual fee of $56K for Intterra software)	Physical Factors - Enable all response/fleet vehicles with software. Institutional Factors - Coordination across multiple responder and traffic management agencies; privacy concerns. Operational and Maintenance Factors - staff training; regular software upgrades.

Strategy	Description	Benefits	Estimated Cost	Influencing Factors
Transit and Demand Management Strategies				
Real-Time Transit Information	Transit agencies can disseminate both schedule and system performance information to travelers through a variety of applications, in-vehicle, wayside, or in-terminal dynamic messages signs, as well as the internet or wireless devices. Coordination with regional or multimodal traveler information efforts can also increase the availability of this transit schedule and system performance information.	- Enhanced passenger convenience - Increased attractiveness of transit - Improve travel experience for transit user - Potential for increased ridership and revenue - Improve schedule adherence by 9 to 23% using AVL/CAD systems (study based on information from Portland, Milwaukie, and Baltimore)	$1 - 4 million for a real-time transit information system $7,000 per "next stop" annunciator	Physical Factors - Provide system interface and GPS equipment on all transit vehicles. Ensure wireless communication capabilities. Institutional Factors - Coordination and integration between agencies (providing transit signs on agency owned ROW). Operational and Maintenance Factors - Maintaining accurate and reliable GPS equipment; regular software updates; staff training.
Support Transportation Demand Management (TDM) Strategies	Promote travel that reduces overall demand on the system such as: bus transit, carpool, and non-peak hour commuting.	- Improves commuter mobility - Makes travel times more reliable during peak hours - Reduces non-recurring delay for planned events - Improves freight mobility - Makes travel times more reliable during non-peak hours	Variable	Physical Factors - n/a Institutional Factors - Coordinate with employers and event managers to promote TDM strategies; public education. Operational and Maintenance Factors - staff time for public outreach.
Support Active Demand Management Strategies	Active demand management strategies include using real-time information to dynamically adjust user demand. Strategies include dynamic pricing, on-demand transit, and dynamic ridesharing.	- Improves commuter mobility - Makes travel times more reliable during peak hours - Reduces non-recurring delay for planned events - Makes travel times more reliable during non-peak hours	Variable	Physical Factors - Communication interface between agencies; real-time data collection; modeling capabilities; integration of various ITS components across agencies. Institutional Factors - Coordinate agreements and policies across agencies (state, local, transit); decision matrix. Operational and Maintenance Factors - staff management of system and training.
Infrastructure Management Strategies				
Targeted Roadway Improvements/Widening (Increasing the length of merge areas and acceleration lanes)	Construct targeted roadway improvements to meet current standards for acceleration and merge areas.	- Improves safety - Improves commuter mobility - Makes travel time more reliable during peak hours - Improves freight mobility - Makes travel time more reliable during non-peak hours	Cost is over $10,000,000	Physical Factors - Limited widening options on I-90 due to structural constraints. Institutional Factors - Possible ROW agreements with other agencies; funding. Operational and Maintenance Factors - regular roadway maintenance once constructed.
Targeted Shoulder Widening - Auxiliary Lane	Construct shoulder (right or left) to provide an extra travel lane during high demand or high congestion. The shoulder needs to meet roadway construction standards for a regular freeway traffic lane.	- Improves safety - Clears lane blocking incidents faster - Improves commuter mobility - Makes travel time more reliable during peak hours - Reduces non-recurring delay for planned events - Improves freight mobility - Makes travel time more reliable during non-peak hours	Cost is over $10,000,000	Physical Factors - Limited widening options on I-90 due to structural constraints. Institutional Factors - Possible ROW agreements with other agencies; funding. Operational and Maintenance Factors - regular roadway maintenance once constructed.